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LONG-DISTANCE ELECTRIC RAILROADING.

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THE problem of substituting electricity for steam on the trunk lines of the country is of such present importance, the efforts being made to solve the problem are so serious, the difficulties are so great, and the results so meagre, that a general review of the subject cannot be without interest.

The applications of electricity to traction, which I will discuss this evening, may be included under three heads:

1st, — Tramways;

2nd, — Suburban and interurban roads;

3rd, — The field at present occupied by steam locomotives.

In the first two of these applications, the problems presented are practically the same, although the scale of operation is varied. In either case, it is required to operate a considerable number of single cars, or single motor cars and trailers, at frequent intervals. In the third application, however — *i.e.*, in the field now occupied by steam locomotives — the problem is entirely different. Here the necessities of through passenger traffic and of cheap freight transportation demand a few very heavy trains, and the system must be

based on the economical solution of this problem. For tramways and interurban roads a practical and satisfactory solution has been found, although it is possible that more satisfactory methods may be developed. For existing steam roads there is at the present moment no electrical solution which has proved its adaptability.

A very brief history of the development of electric traction up to the present time will be instructive.

Prior to January, 1888, although experimental roads had been built and were in operation in England, Germany, and the United States, yet they were not on a commercial basis, and did not offer any advantages over the then existing traction methods. At that time a road was opened in Richmond, by the Sprague Electric Railway & Motor Company, which in all essential particulars embodied the methods now used.

Mr. Frank J. Sprague graduated from the Naval Academy in 1878. While there he paid especial attention to electricity. I remember him distinctly, as Captain of my gun crew at the school. For not reporting me as often as he might, he earned an esteem which twenty-four years of close association has failed to weaken. After graduation, Mr. Sprague spent six or seven years in the service. He was ordered to special duty at the Paris Exposition of 1881, and had a tour of duty at the Torpedo School at Newport. He resigned in 1885, and with Mr. E. H. Johnson, then President of the Edison Company, formed the Sprague Electric Railway & Motor Company, the object being to develop the application of motors, more especially for traction work. An experimental car was equipped and operated on a small spur of the elevated road. In the latter part of 1886, a contract was hastily closed for the equipment of the Richmond roads, and preliminary work was begun at once; but when the actual condition of affairs was investigated, it was found to be a much more difficult problem than was at first supposed

The railroad company had stated that the maximum grade was from 6 to 7 per cent.; in reality, there were grades as high as 10½ per cent. The tracks were badly laid in streets that were unpaved and muddy, and there were a great many curves of a very short radius. However, the work was pushed forward, and the road was formally opened in January, 1888. As I have said, all the important features of modern electric cars were contained at one time or another in this first road. Series motors were used, with a voltage of approxi-

mately 500 volts at the motor terminals. A successful under-running trolley was developed, a series-parallel control was at first used, and then for reasons which at the time were good, was discarded. A single reduction gearing was at first employed, but afterwards changed to double reduction gearing. The only important feature that did not appear at one time or another in these motors was the use of the carbon brush, which is essential to the successful operation of continuous current railroad motors; this was experimented on, but was discarded, because of the indifferent quality of the carbon used.

On the day that the road was opened, there had been a heavy frost, and mud from the streets had accumulated on the tracks and frozen, the consequence being that there was no ground circuit at times. When the current was made by getting out and pushing the cars until they struck a clean rail, the inexperienced motormen as a rule had the controllers full on, and a number of motors were burned out. The brushes consisted of pieces of brass, set very much as the carbon brushes are now set; the average life of the commutator was not more than two weeks. On the first day, twenty equipments were burned out. For some months the operation of the Richmond road was attended with great difficulties. The motors were not heavy enough for the work; the brushes gave an immense amount of trouble, and the roadbed itself was not fit for heavy traffic. These difficulties were gradually eliminated, and the new roads contracted for took advantage of the experience gained.

The development from the early Richmond experience has been in the direction of making heavier and better motors, of using carbon brushes, and a series-parallel control. The essential parts of the system are, however, adhered to.

As the economy and capacity of electric equipments increased, the city roads were pushed further into the suburbs, and finally roads were built from cities to outlying towns and between cities. This movement is now probably at its maximum; a great number of interurban and suburban roads have been built and more are under construction. The interurban railroad system is simply an extension of the city tramways. The same system is used with the few modifications necessary for the much heavier cars and the much higher speeds required outside the limits of towns.

On some of the interurban roads very handsome and heavy cars are used, fitted out very much as steam cars are, and approximately

of the same size, with speeds up to as much as 60 miles per hour. In fact one road is building special cars which will attain a maximum speed of 75 miles per hour, and make a schedule speed of 60 miles an hour.

When electric roads operated within a short radius, it was the custom to have a central station where the voltage was approximately that intended for use on the cars, and to distribute directly from feed wires connected at the station and to the trolley wire. When the distances became greater, a number of stations employed "boosters" for the outlying districts, the voltage being raised at the station to such an amount that the loss of potential in the feeders would be neutralized, the voltage in the outlying districts being the same as the voltage in the station. When the radius became still greater, as in the case of interurban roads, neither of these systems were applicable, and it is the custom now to distribute, when the distances are considerable, by a high potential alternating current, which, at certain points along the line, is reduced in voltage and changed to continuous current by means of rotary converters. This continuous current has a voltage of from 500 to 600 volts, and the operation from such a sub-station is similar to the operation from an ordinary central station. The advantage of this system is that it allows a very considerable length of line to be operated from a single station, thus giving economy in the generation of power, while it does not interfere with the direct current system of operation on the cars. The disadvantages are in the cost, the losses, and the attendance in the sub-station. If the service is frequent, the average load on the sub-stations will be fairly constant, but where the service is infrequent, then the load factor of these stations is very low. This has in a great many cases been remedied by putting storage batteries in the sub-stations and running the rotary converters at a constant load, the fluctuations being taken up by the storage battery.

It should be specially noticed in this connection that it is of extreme importance that the load on all parts of the system should be kept as nearly constant as possible; if the load on the central station fluctuates, the capacity of the station must be great enough to take the maximum load; this increases its cost and decreases the economy of operation. In the sub-station the same thing holds true, and it is also true of the feed wires. As the loss in the feeders

changes with the square of the current, it will take approximately twice as much copper for the same loss with a 50% load factor, that is where the average power is 50% of the maximum, as it would if the load factor were unity.

The system sketched above is, then, applicable to the first two classes of traction considered, and it is applicable because they embody a frequent service with small units.

When we consider steam railroad traffic, however, we meet an entirely new set of conditions. For through passenger service, a single car, or even two cars, are not enough to give the comfort to which the traveling public is accustomed. This requires heavy trains consisting of a number of cars. Even for a certain class of suburban traffic, where a large amount of travel is concentrated at certain hours, heavy trains must be used, and a large amount of power utilized for each train.

As far as freight is concerned, the great development in railroads in the past twenty years has been in the direction of increasing the size and capacity of the cars and the weight of the train. For freight, especially bulk freight, the minimum of cost is attained with the maximum weight of train.

The annual reports of the more important roads show clearly the tendency to heavier cars and trains for freight. The average train load on the Pennsylvania Railroad has increased in twenty years by about 75% and the capacity of the cars is over 100% greater.

Under these conditions, 500 to 600 volts continuous current motors, receiving current either directly from a central station or from sub-stations, are not applicable. The possibilities of congestion of traffic, especially of freight congestion, make the capacity of sub-stations enormous as compared with the average power required on the line, and there is required in addition an immense amount of copper for the feeders.

Another difficulty is in the large amount of switching to be done, much of it of a complicated nature. If electricity is to be used in terminals and freight yards, a locomotive must be designed which is economical at all speeds and which is under perfect control, and current must be supplied to these locomotives by some means which will not endanger the lives of the train hands. Railroading is dangerous enough as it is, and any additional source of danger must be avoided.

To obviate these difficulties, several plans have been proposed.

The first is to use alternating current motors on an electric locomotive, the locomotive to be supplied with high potential currents directly from the generating station, these currents to be applied at once on the motors or to be reduced by transformers carried on the locomotive. A modification of this is to generate a very high potential at the station and to reduce it to a lower potential by means of static transformers along the line, and to use this lower potential on the locomotive. These plans obviate the difficulty of the rotary transformers that would be needed for changing an alternating to a continuous current, and are cheaper in this way. The alternating current motors also allow higher potentials to be used on the motors, so that it would be possible, for instance, to generate at the station 20,000 volts and transform along the line to 3,000, and apply the 3,000 volts to the motors.

To apply this system practically, there have been a number of experiments made, and some roads are operated on this basis. One method that has been used — the only alternating method now in commercial operation — is to supply three-phase currents either directly to the motor or to reducing transformers which are connected to the trolley wires and are carried on the car. As a rule, this system is installed by using two trolley wires above each track, the rails being taken as a return. A number of small mountain roads in Switzerland and one road in Italy are operated on this basis. I will refer to them later.

Another method that has been proposed several times and is being experimented on by the Oerlikon Works in Switzerland, is to use a single phase alternating current motor on the locomotive, connected to a continuous current dynamo, the current from the dynamo to be used to run continuous current motors on the axles. The regulation of the locomotive is obtained by varying the strength of the field of the continuous dynamo.

Still another method, proposed by Mr. Arnold, is to use a single phase alternating motor, which, when working at normal power, will run the train, when running below normal power will store up air in a receiver, and when more than normal power is required, both motor and compressed air are used.

A further plan just proposed by the Westinghouse Company, and which is being installed on a road between Baltimore and Washington, is, in many ways, the simplest of all. It is well known that a series motor will run on an alternating current circuit, the alterna-

tions in the field and armature occurring together, the effect being, under certain circumstances, much like that of continuous current. The Westinghouse Company proposes to take a motor like an ordinary street car motor, to laminate the entire magnetic circuit, so that there will be little waste due to the alternations of the field, and to supply this with alternating current of $16\frac{2}{3}$ periods. The characteristics of such a machine are very similar to those of the present continuous current type of series motors, while its regulation is easily effected without breaking the circuit by introducing a variable E.M.F. either working with or against the impressed E.M.F. This variable E.M.F. depends on the position of the armature of an auxiliary transformer in the circuit.

To take these methods up in more detail — the three-phase system has been, as a rule, advocated by European engineers. At first glance it presents a number of advantages over continuous current systems, and it has been practically operated in Switzerland. It has not met with any favor in this country, and its achievements on the other side have not been such as to inspire any great hope of its ultimate success. The roads in Switzerland show practically nothing except that a three-phase alternating motor can drive a car — a thing which was very well known before. There is no railroad problem involved in their operation. The cars are small, and the voltages used are in no case above 750 volts — the limit imposed by the Swiss government. The most ambitious three-phase road is one in Italy, running from a point a few miles out of Milan, called Lecco — a total distance of 60 miles. A particular interest attaches to this because the system is that of the Ganz Company, which was strongly recommended by English engineers for the Yerkes tunnels in London. The position of the English engineers in this matter was warmly opposed by Mr. Yerkes and some American engineers, and an ordinary system, very similar to that used on the elevated roads in Boston, New York, and Chicago, was adopted. It seems that very few experiments had been tried on the Ganz three-phase system before this discussion came up, and the road in Italy embodies most of the features that were to appear in the London project. The Lecco road was to have started a year ago the first of September. I was on the road the first of this September, and it was not then in commercial operation; an experimental car made trips over a part of it. Roughly, the system is this: Power is generated at a waterfall in about the middle of the line, and is distrib-

uted at 20,000 volts to sub-stations where it is reduced to 3,000 volts by static transformers. The overhead system consists of two wires over each track, the tracks acting as a return for the third leg of the circuit. The current is collected by a trolley consisting of two metallic rollers about two feet long, mounted on a wooden axle. The rollers are separated from each other by about six inches of treated wood. The roller is held against the trolley wires by compressed air. There are four motors on a car — two of them for permanent use; the other two are merely used in starting. In starting, the fields of the secondary motors are put in series with the armatures of the permanent motors, and a water resistance is put in the armature of the secondary motors. This water resistance is quite ingenious, and will possibly some day work very well, although they have had a great deal of trouble with it up to the present. The plates through which the current passes are stationary; the liquid is forced by compressed air into the tank which contains the plates, and the resistance decreases as the immersed surface increases. When a certain train velocity is reached — which is approximately at half the full speed of the car — and the entire resistance is cut out, the circuits are broken, the secondary motors are cut out, and the permanent motors are put across the supply circuit, with the water resistance in the circuit of the permanent armatures. Then this resistance is gradually cut out as before.

I have not time to go into the difficulties that the Ganz Company has had with this road, but that they are serious is shown by the fact that they are over a year behind the proposed date of opening. The service required is not the heavy service that we need in our railroads, and if it was, the great uncertainty of operation that has been shown would make the system impossible of operation. A great difficulty — in fact, almost a fatal difficulty — with such a scheme is in the liability of trouble with overhead wires. A two-track system, with four wires overhead, these wires having a great difference of potential between them, is almost certain to cause trouble even on a straight track, and where there is switching, the complication becomes enormous.

There is another difficulty of a more technical nature, which depends on the unbalancing of the circuit due to the rail return. I will not discuss this any more than to state that it decreases the normal capacity of the motors — *i.e.*, for a given output they heat more than they should.

It is interesting to note that very close to this road, running about eighty miles out of Milan, is a road equipped by the General Electric Company. The railroad problem is the same in both cases. The General Electric Company finished their road over a year ago, before the time it was promised, and it has been operating successfully ever since, in fact its service goes beyond the guarantees that were given.

Taking up the system of the Oerlikon Company, it has some advantages in that it requires but little trolley wire over the track, and affords an excellent means of regulating the motors. Its disadvantages lie in the fact that it interposes between the trolley and the motors a transforming station which is not only expensive, but adds greatly to the complexity of the system. For heavy railroad work, between this and the three-phase system, I would unquestionably choose the Oerlikon method. Mr. Arnold's proposition has yet to be tried. It affords an ingenious, if doubtful, solution of the railroad problem, but I am very much afraid that its complexity will prevent its adoption. Without going into any particular reason why, it does not sound like an operative system. The Westinghouse system promises much in the way of simplicity and applicability to the heavy problems of steam railroad traffic. A series motor has the advantage that it is to a certain extent self-regulating. If a great torque is required, the armature slows down, the field is strengthened and the maximum effect is obtained. The details of the apparatus have not yet been given out by the Westinghouse Company, but the fact that they have experimented for some time past in their own yards, and have closed a contract for an equipment, shows that they thoroughly believe in its success. One disadvantage is in the low period, which will require large static transformers; but if this is the only difficulty, we can afford to overlook it.

To sum up; as far as the substituting of electricity on steam roads goes, our present methods of electrical traction are not applicable. No method has yet been in successfully practical operation that solves the problem, but our most brilliant experts, having already solved the problem presented by tramway and interurban traction, are seriously attacking the field. The steam railroad companies are becoming interested in the matter, and are lending their coöperation, and we may expect the same results that have been obtained in the past, *i.e.*, that the problem will be solved, and satisfactorily solved.

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CONTRIBUTION FROM THE LABORATORY OF ORGANIC CHEMISTRY.

THE DECOMPOSITION OF DIAZONIUM SALTS WITH PHENOLS.

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SOME time ago Hirsch[1] undertook a careful study of the preparation of phenol from aniline by means of the diazo reaction, on account of the fact that the yield of phenol was much less than that required theoretically by the equation usually written to express the decomposition of a diazonium salt with water. It was found that a number of reactions take place simultaneously. Among the products of the decomposition was *p*-oxydiphenyl. This compound was shown to be the product of the action of the diazonium salt on a part of the phenol produced in the decomposition. As a result of the study of this reaction, Hirsch showed that when a cold aqueous solution of a diazonium salt was treated with a large quantity of phenol, the diazo compound was extracted from the water. The phenol solution was stable in the cold, but decomposed when heated with the evolution of nitrogen and the formation of oxydiphenyl, phenyl ether, and ill-defined products which were not isolated. Hirsch endeavored without success to extract the diazonium salts from an aqueous solution by substances other than phenol. This method of preparing diphenyl derivatives was, therefore, limited to the decomposition of various diazo compounds with this one substance. The method was not a very satisfactory one, in that large quantities of phenol were used in the extractions, and a number of fractional distillations were involved.

In studying the preparation of phenol from aniline in this laboratory we were led to the view that when a diazonium salt decomposes in the presence of water and a phenol, it reacts to a much larger

[1] Ber. d. Chem. Ges. 23, 3705.

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extent with the phenol than with the water. It seemed possible, therefore, that the preparation of diphenyl derivatives by this reaction might be carried out in aqueous solution, and that the method might be developed into a general one for the preparation of hydroxyl derivatives of diphenyl by using, instead of phenol, other compounds of the same class. To test this view, experiments were carried out with benzene-diazonium salts and phenol, pyrocatechin, resorcin, and hydroquinone. It was found that the phenols entered into the reaction when the decomposition of the diazonium compound took place at 75° to 100°, and that good yields of diphenyl derivatives were obtained.

In carrying out the reaction, the phenol, mixed with a small quantity of water and heated to about 90°, was treated cautiously with a cold aqueous solution of the diazonium salt. A vigorous reaction took place, nitrogen was evolved, and a dark, heavy oil separated. When phenol was used, the reaction-product was found to consist of *p*-oxydiphenyl, *o*-oxydiphenyl, phenyl ether, and a tarry mass which could not be purified in any way. The amount of oxydiphenyl obtained was equal to about one-half the weight of aniline used. The reaction furnishes, therefore, a good method for the preparation of this compound. The diphenyl compounds were separated from the reaction-mixture by distillation with superheated steam. This method appears to be much more expeditious than fractional distillation which has been used in the past.

The experiments show that by means of benzene-diazonium salts, a phenyl group can be introduced readily into a benzene ring which contains an hydroxyl group. As usual, the hydroxyl group sends the entering radical to the para position. In the case of phenol, about 90 per cent. of the oxydiphenyl obtained was the para compound. About 10 per cent. of an isomer was obtained which in all probability was the ortho compound. The substance was not obtained in quantity sufficient to make it possible to determine its structure. In the reaction, the hydrogen atom of the hydroxyl group is, to some extent, replaced by phenyl and an ether results.

The decomposition of benzene-diazonium chloride with pyrocatechin proceeded in the same general way. The chief reaction product was a dioxydiphenyl. The substance formed in the next largest amount was shown to be *o*-oxyphenyl ether, which was formed by the replacement of a hydrogen atom of one of the hydroxyl groups by phenyl. A

very small quantity of a substance, which was evidently an isomer of the dioxydiphenyl obtained, was also isolated.

In resorcin there is one position in the benzene ring which is para to one hydroxyl group and ortho to the other. As the orienting influence of both groups is thus, at the same time, directed to this place and the chances for the formation of isomeric compounds accordingly reduced, it seemed probable that the reaction would be a smooth one. The results of the experiments were surprising, therefore, when no diphenyl derivatives could be isolated. The only product which was found was the azo compound, notwithstanding the fact that the reaction was carried out at 100°.

Preliminary experiments only have been carried out with hydroquinone. These indicate that the reaction proceeds in a manner analogous to that with pyrocatechin. The chief product of the reaction in this case appears to be *p*-oxyphenyl ether and not a diphenyl derivative, however. This difference is due, no doubt, to the fact that there is no vacant position para to an hydroxyl group, and as a consequence, the hydroxyl hydrogen is replaced to a larger extent than is the case with pyrocatechin. To some extent, however, a phenyl group is introduced into the ring and a dioxydiphenyl is formed.

The introduction of a phenyl group into the ring in pyrocatechin and hydroquinone modifies the properties of these compounds. The resulting substances show the reactions of the simpler benzene derivatives, but their reactivity is greatly increased. For example, the phenyl derivative of hydroquinone is oxidized by atmospheric oxygen to a dark blue compound, which can be reduced by sulphur dioxide to a colorless substance.

The ethers produced in the reaction are stable, and do not reduce an ammoniacal solution of silver nitrate.

The number of hydroxyl groups in the compounds was determined by preparing the acetyl derivatives. In some cases the methyl ethers also were made.

The descriptions of the compounds prepared from hydroquinone will be given in a subsequent paper.

Experimental.

Decomposition of Benzene-Diazonium Sulphate with Phenol.— The decomposition of benzene-diazonium sulphate with phenol was car-

ried out under a variety of conditions. The method finally adopted was as follows: The diazo compound was prepared by treating a cold solution of aniline sulphate, made by dissolving 40 grams of aniline in a mixture of 80 grams of sulphuric acid and 40 c.c. of water, with a solution of 36 grams of sodium nitrate in 80 c.c. of water. The cold solution was then poured in small portions, with constant shaking, into a large flask containing 80 grams of phenol, which was heated on a boiling water-bath. During the reaction a heavy black oil separated and much nitrogen was evolved. In order to separate the products of the reaction, the mixture was distilled with steam and the distillate was collected in fractions. In the first experiment ordinary steam was used and fourteen fractions of 100 c.c. each were collected. The first nine fractions were found to contain the excess of phenol: in fractions 10 to 14 there were a few needle-shaped crystals, which melted at 67.5° and proved to be *o*-oxydiphenyl. As the major part of the reaction-product was only slightly volatile with ordinary steam, the product of a second decomposition was distilled with superheated steam. The oil formed in the reaction was separated and put into a 500 c.c. flask, which was heated to 150° in an oil bath. The steam, after passing through a three-eighths inch iron pipe heated in a thirty-inch combustion furnace, was at a temperature of 140° to 160° when it entered the flask. Under these conditions all the oxidiphenyl had distilled over when 700 c.c. of water had been collected. The distillate was collected in fractions of 50 c.c. each. Numbers 1 to 5 contained an oil, 6 to 7 a semi-pasty mass, and 8 to 14 a white solid. The oil contained the excess of phenol and some *o*-oxydiphenyl, fractions 6 to 7 consisted of a mixture of the ortho and para compounds, and the white solid was almost pure *p*-oxydiphenyl.

The phenol recovered from the first fractions of the distillate weighed 44 grams. Thirty-six grams had, therefore, entered into reaction with the diazo compound, whereas the theoretical quantity required by the following equation for the aniline used is 40 grams.

$$C_6H_5.N_2SO_4H + C_6H_5OH = C_6H_5.C_6H_4OH + H_2SO_4 + N_2.$$

The separation of the isomeric oxydiphenyls was best effected by crystallization from hot petroleum ether (b. p. 50°-80°) in which the para compound is only slightly soluble in the cold, and in which the ortho compound is much more soluble both hot and cold. *p*-Oxydiphenyl crystallizes well from hot 20-per cent. alcohol.

As a result of the decomposition, there was obtained from 40 grams of aniline 20 grams of pure *p*-oxydiphenyl and 1.5 grams of the isomer. There was a large amount of the reaction-product which was not volatile with steam. It consisted of a black brittle mass, which dissolved in sodium hydroxide and was precipitated from this solution by the addition of hydrochloric acid. The mixture probably contained substances which were formed by the introduction of more than one phenyl group into the benzene ring.

Hirsch noted that an isomer of *p*-oxydiphenyl is formed in the decomposition of benzene diazonium salts with phenol, and assigned to it the ortho structure. No analyses are reported and the properties of the compound are not given. The amount of material obtained by us was not sufficient to warrant an investigation of the structure of the compound. It is, in all probability, an ortho substitution-product produced as a result of the well known orienting influence of the hydroxyl group. An analysis of the compound melting at 67.50 resulted as follows:

0.1308 gram of the substance gave 0.4047 gram CO_2 and 0.0700 gram H_2O.

	Calculated for $C_{12}H_{10}O$	Found
C	84.71	84.31
H	5.88	5.91

The compound crystallizes in colorless needles, which are stouter than those of the para compound.

Decomposition of Benzene-Diazonium Chloride with Pyrocatechin. —As a result of a preliminary experiment it was found that the chief products of the reaction between benzene-diazonium salts and pyrocatechin were dioxydiphenyl, *o*-oxydiphenyl ether, and an oil which could not be distilled without decomposition. Of a number of methods of separating the mixture into its constituents which were studied, the one described below was found to be the best.

The diazo compound was prepared by treating a mixture of 40 grams of aniline in 100 grams of concentrated hydrochloric acid diluted with 100 c.c. of water, with 32 grams of sodium nitrate dissolved in 80 c.c. of water. This solution was poured very slowly into a mixture of 50 grams of pyrocatechin and 50 c.c. of water, which was heated at about 75°. The product was distilled with steam and the distillate collected in fractions. The first fractions,

which contained an oil, were extracted with ether, from which 6.5 grams of phenol were obtained. The solid volatile with steam was found to be *o*-oxydiphenyl ether. About 4 liters of water were necessary to carry over the phenol and the 4.6 grams of the ether formed in the reaction. The solution in the flask was decanted from the non-volatile oil and evaporated to a small bulk. The dioxydiphenyl which separated was filtered off, and from the filtrate 21 grams of pyrocatechin were recovered. Thirty-nine grams had, therefore, entered into reaction instead of 47 grams — the theoretical quantity for a reaction between an equal number of molecules of the diazo compound and the phenol.

The non-volatile oil was extracted three times with boiling water. In all, 2.5 liters were required to dissolve the dioxydiphenyl. On cooling, 5 grams of the compound crystallized out, and 4 grams in addition were obtained on evaporation. The oil insoluble in water weighed 10 grams. It dissolved in alkali, however, and was, no doubt, a mixture of complex phenols formed hy the introduction of more than one phenyl group into the pyrocatechin molecule. An attempt was made to distill this oil. After about one gram of a colorless substance had distilled over at 220° to 250°, total decomposition took place. This distillate, after crystallization from a mixture of toluene and petroleum ether, melted at 147.5° to 148.5°. The substance reduced silver nitrate, gave a white precipitate with lead acetate, and produced a light green color with ferric chloride, which changed to a reddish brown on standing, and to a deep violet on the addition of sodium carbonate. The compound was evidently a pyrocatechin derivative and probably an isomer of the dioxydiphenyl formed as the chief product of the reaction.

The reaction between benzene-diazonium salts and pyrocatechin was brought about in a number of ways, in order to determine the effect of the conditions on the yield of the various products of the reaction. The decomposition was effected by raising gradually the temperature of a mixture of the diazo compound and the phenol, by bringing about the reaction at different temperatures, and at 75° and at 100° in the presence of copper powder. In no case were the yields as good as in the experiment described above.

o-Oxydiphenyl Ether. — About 4.6 grams of this substance were obtained from 40 grams of aniline. The compound crystallizes from dilute alcohol in flat needles, and from petroleum ether in well-formed

six-sided needles terminated by domes. It is slightly soluble in hot water, from which it separates on cooling in long needles. A cold saturated aqueous solution contains .11 gram to the liter. *o*-Oxydiphenyl ether melts at 105° to 106° and has an aromatic odor. It is very soluble in carbon bisulphide, benzene, and glacial acetic acid, less soluble in toluene, and only slightly soluble in petroleum ether. It gives no color with ferric chloride and shows none of the characteristic reactions of pyrocatechin. The results of an analysis follow:—

0.1105 gram substance gave 0.3125 gram CO_2 and 0.0553 gram H_2O

	Calculated for $C_{12}H_{10}O_2$	Found
C	77.42	77.08
H	5.37	5.56

A molecular weight determination, using alcohol as the solvent, gave 176 as the result instead of 186, the theoretical number.

The acetyl derivative was made by heating the phenol with an excess of acetyl chloride. After the product so obtained had been treated with sodium hydroxide, it distilled without decomposition at 358° to 360° (uncorrected). The compound is a thick oil, which dissolves in the usual organic solvents. An analysis gave the following results:—

0.1251 gram substance gave 0.3386 gram CO_2 and 0.0607 gram H_2O.

	Calculated for $C_{14}H_{12}O_3$	Found
C	73.68	73.82
H	5.26	5.39

The methyl ether of *o*-oxydiphenyl ether was prepared by heating a solution of the phenol in methyl alcohol with the calculated quantities of potassium hydroxide and methyl iodide. The compound crystallizes from methyl alcohol in long, flat, six-sided crystals. It dissolves in the ordinary solvents and melts at 77°. The formation of this compound and of the mono-acetyl derivative described above shows that the structure assigned to the *o*-oxydiphenyl ether is correct. An analysis of the methyl ether gave the following results:—

0.1074 gram substance gave 0.3063 gram CO_2 and 0.0589 gram H_2O.

	Calculated for $C_{13}H_{12}O_2$	Found
C	78.00	77.78
H	6.00	6.09

Dioxydiphenyl. — Nine grams of this compound were obtained from 40 grams of aniline. The crude substance which was separated from the original reaction-product by extraction with water, was dark brown in color and somewhat gummy. In this condition it is best purified by crystallization from hot petroleum ether, in which it is only slightly soluble. It melts at 136° to 136.5° and boils above 360° without decomposition. It is very soluble in alcohol, chloroform, and ether, less soluble in carbon bisulphide, petroleum ether, and hot water. A cold saturated aqueous solution contains 1.6 grams per liter. The compound gave a light green color with ferric chloride, which changed to a reddish brown on standing, and which was changed to a deep violet on the addition of sodium carbonate. It reduces silver nitrate and gives a precipitate with lead nitrate and with bromine water. No marked coloration is produced when the substance is heated with phthalic anhydride and sulphuric acid. An analysis gave the following results: —

0.2048 gram substance gave 0.5826 gram CO_2 and 0.1022 gram H_2O.

	Calculated for $C_{12}H_{10}O_2$	Found
C	77.42	77.53
H	5.37	5.54

The diacetyl derivative was obtained by heating the phenol with an excess of acetyl chloride. It crystallizes from alcohol in long six-sided crystals, which melt at 77° to 77.5°. The analytical results were as follows: —

0.1285 gram substance gave 0.3341 gram CO_2 and 0.0628 gram H_2O.

	Calculated for $C_{16}H_{14}O_4$	Found
C	71.11	70.91
H	5.18	5.43

Two dioxydiphenyls are possible as the result of the introduction of a phenyl group into the benzene ring of pyrocatechin. In one compound the group introduced is ortho and meta to the two hydroxyl groups: in the other it is para and meta to these groups. An attempt was made to determine which of these structures belonged to the dioxydiphenyl formed as the chief product of the decomposition of the diazonium salt with pyrocatechin. The phenol was converted into the corresponding dimethyl ether, which was then oxidized. It was expected that in this way the phenyl group would be converted into carboxyl and, as a result, a dimethoxy-benzoic acid obtained. If the phenyl group occupied the position para to one of the hydroxyl groups, the oxidation-product would be veratric acid, a well described compound. The oxidation was brought about under a variety of conditions with chromic acid and with potassium permanganate. Only when the last-named substance was used could any oxidation-product be isolated, which in this case proved to be benzoic acid. The structure of the compound was not established, therefore, but on account of the usual directing influence of the hydroxyl group and the results with phenol, it is highly probable that the substance is 3, 4-dioxydiphenyl.

Boston, October 27, 1902.

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ANTISEPTICS, AND THEIR USE IN THE PRESERVATION OF FOOD.[1]

By SAMUEL C. PRESCOTT.

If we compare the processes of food preservation in use today with those commonly practiced thirty or forty years ago, we shall find not merely a considerable increase in the number of methods, but also an immense development in the application of the older methods. While as a whole the development of these methods has been of great benefit to mankind, it has also given rise to some of the most perplexing and difficult questions which have ever been put to the sanitarian or hygienist, and one of these concerns the use of antiseptics. This particular subject has been for a long time a source of much contention, and its satisfactory solution is far from having been reached. It may be of interest, however, to inquire briefly into the present status of the question and its bearing upon the subject of food preservation. In order to view the matter in its proper perspective some general statements as to the methods and aims of food preservation may be timely. It may be well to state at the outset that the general aim in all these processes is the same, namely, to prevent putrefactive or fermentative changes, and thus to make the surplus food of one place or one time available in another place or at another time.

Fermentation, Putrefaction, and Decay. — Unless some means are taken to interfere, nearly all foods are likely to undergo important changes caused by the action of extremely minute living organisms, variously known as germs, bacteria, microbes, bacilli, etc., or by the so-called unorganized ferments. The chemical changes thus brought about by the activity of micro-organisms we sometimes designate as fermentation processes, although it is more convenient in general to subdivide them into the two classes, fermentations and putrefactions. By fermentations we mean changes taking place spontaneously in

[1] Read before the joint meeting of Atlantic States Canned Goods Association and Western Canned Goods Association, at Milwaukee, February, 1902.

sugary or starchy foods, the microbes transforming these substances into acids for the most part, and thus giving rise to "souring," as in sour corn and sour peas. Putrefactions, on the other hand, are the changes which are brought about by the bacteria in the more complex proteid or albuminoid foods, such as meats, which are rich in nitrogen. Here, instead of the formation of acids, there may be a great variety of products, including malodorous gases, and other bad smelling compounds, and sometimes poisonous bodies, the so-called ptomaines, which if taken in with the food give rise to sickness and symptoms of poisoning. The bacteria causing putrefaction live anaërobically, *i.e.*, they do not require free contact with the air. "Decay" is a term sometimes used in a broad way to describe any of these processes, and sometimes used in a more specific way to indicate the changes taking place in albuminous matters in contact with the air, in which case no bad smelling compounds are formed unless putrefactive processes are going on within the food at the same time.

Methods of Food Conservation. — Of the processes which may be employed in food conservation, we may easily distinguish four principal kinds:

1. Cold Storage.
2. Preserving, pickling, and drying.
3. Canning.
4. The use of antiseptics.

The desired result may be obtained by the use of a single one of these methods, the choice depending upon the character of the food to be preserved, or they may be used in combination, in which case the fourth method is generally combined with one of the others. Let us now briefly consider these four methods, and determine the underlying principle in each.

Cold Storage. — It is a well-known fact that almost all kinds of food "keep" better in the cold than in warmth, and it has become a general practice to use ice in the preservation of our daily foods. In addition to its convenience and general usefulness, there is a sound scientific principle underlying this practice, for we find that the microorganisms of fermentation and putrefaction are so much weakened or so stiffened by cold as to be rendered inert, and therefore, for the time being, absolutely harmless. Obviously, this method can be employed only when it is desired to conserve materials for comparatively short periods of time, although with proper refrigerating appliances

some classes of food stuffs might be kept forever. This method is of inestimable value, for by it we are able to keep many foods fresh almost indefinitely, and may even transport fresh foods over long distances. It should always be borne in mind, however, that refrigeration is not sterilization, and when foods taken from cold storage are warmed, the processes of decomposition proceed as vigorously as ever. Consequently, foods should always be consumed or cooked immediately after leaving the cold chambers. This method is a process of prevention of the growth and activity of microbes, not of sterilization.

Preserving, Pickling, and Drying. — These processes are analogous in a general way to the preceding, inasmuch as they are not sterilizing processes, but depend for their efficiency upon such modification of the physical properties of the food substance that bacterial growth cannot take place. In order that germs may develop abundantly, a comparatively large amount of water is necessary, and if the percentage of water is diminished, as by drying, the germs are not able to thrive until the conditions again become favorable. In pickling in brine and preserving with sugar, a slightly different action takes place, for here we increase the density of the medium by the addition of these substances which have a strong affinity for water. The concentrated solutions thus formed tend to absorb more water by osmosis, and when microbes come in contact with such substances, the water is extracted from their bodies and they are rendered inert and innocuous. But, as with the cold storage of foods, protection is afforded only temporarily, for if we weaken the strength of the brine or sugar sufficiently, we find that the vitality of the bacteria has been merely diminished, that in reality we have had a case of suspended animation, and that fermentative processes will go on again vigorously.

Canning. — This method of food preservation is of the very highest importance and value. While by the use of the foregoing it has been possible to establish a temporary immunity against the attacks of the fermentation microbes, by hermetically sealing the foods in cans or jars and subjecting them to sufficiently high temperature we may guard permanently against any such invasion. In other words, if we *sterilize* our food materials we have no need to fear decomposition or fermentation, for we have destroyed the cause of such changes. Absolute sterilization means the killing of all bacteria, so that we have here the most nearly ideal of all preservation processes

in actual use, when considered from the fermentation and sanitation expert's point of view. This subject has already been so thoroughly discussed that further comment is unnecessary.

Use of Antiseptics or Preservatives. — We come now to the last of the list of methods mentioned, and the one which must be viewed with the least satisfaction and confidence because of the grave questions as to the effect of the chemical substances used as preservatives upon the health of the consumers.

By a preservative or antiseptic we mean a chemical substance which, owing to its toxic or poisonous action on microörganisms, is capable of retarding or preventing fermentation and putrefaction. If the toxicity is sufficiently great to *kill* the organisms, we speak of the substance as a disinfectant. The distinction between a disinfectant and an antiseptic is, then, a difference in strength and germicidal power, for in very small amounts the strongest poisons act only antiseptically; that is, they do not produce the death of the germs. Preservatives such as are used in food substances are all antiseptic, but it is evident that not all antiseptics can be used as preservatives. The preservatives in common use, although sold under a variety of names, are in reality comparatively few in number as shown by the analyses which have been made from time to time. The most important of these are boric or boracic acid and borax, salicylic acid and sodium salicylate, benzoic acid and sodium benzoate, fluorides, sulphites, and formaldehyde. Borax or boric acid, or mixtures of the two, are extensively employed in the preservation of meats, fish, and dairy products. Salicylic acid and its salts are used for fruits and vegetable products chiefly, such as jams and jellies, and in beverages. Sulphites are used in the same food substances as salicylic acid, and also to some extent for meat. Benzoic acid finds use in beverages, and in fruit and vegetable preparations such as catsups. Formaldehyde is especially used for milk, and fluorides are used in some beverages, especially beer.

From authoritative analyses of 67 preservatives it has been found that 33 contained either borax or boric acid as the most active constituent, 10 contained sulphites; 8, salicylic acid or its sodium salt; and 7, benzoic acid or its sodium compound, while the others were either mixtures of the foregoing or were composed of other substances. Analysis has also revealed the fact that dealers sometimes sell the same compound or mixture under different names and at different

prices, and often these substances are described as perfectly harmless, and at the same time of the highest germicidal efficiency. It may also be of interest to know that all the preservatives commonly used in foods can be easily detected by the skilled chemist, in spite of the statement sometimes made by agents that certain of their wares baffle chemical examination, a statement which amounts to a confession that these are regarded as suspicious.

But of all the questions relating to the use of preservatives, that of the effect of the substances which they contain upon health is of greatest moment, and is likewise the most difficult of solution. Generally speaking, those substances which exert a harmful effect upon bacterial life will produce a similar effect upon higher organisms, although it may be to a much less degree; and this fact forms the basis of nearly all objections to the use of antiseptics. That is, the general effect of such substances on living things is everywhere similar, although differing in intensity. For example, corrosive sublimate is one of the strongest bacterial poisons known, and also one of the poisons most deadly for human beings, and the same rule holds good for most of the substances of very strong antiseptic or disinfectant character. Obviously, nothing should be added to foods which is in itself inimical or poisonous, or which interferes with the normal processes of digestion. And here it should be borne constantly in mind that the old saying, "What is one man's meat is another man's poison," fits the case exactly. It may be possible, perhaps, for strong, healthy individuals in good condition to eat foods containing a small amount of toxic antiseptic without serious consequences. It is entirely another matter, however, when invalids or delicate young children are given such foods, and the result is likely to be far from desirable. Further than this, we do not know with certainty as to the cumulative effect of these substances, that is, whether they are readily taken care of and excreted, or whether they are retained within the body until considerable amounts have accumulated. We do know, however, that in large doses these substances almost invariably act harmfully. On the other hand, it is also possible to conceive that some of these substances are no more harmful than common salt, though this is at least doubtful.

After reviewing many articles written by well known physiologists in Germany, France, England, and America, I have been strongly impressed with the conflicting and inconclusive character of

the evidence. For example, Liebreich declares that boric acid and borax have no harmful effect when consumed in small quantities, while almost at the same time, Halliburton asserts that all preservatives should be forbidden by law. Lebbin and Kallman made experiments on animals to show that sulphites were absolutely harmless and less poisonous than salt, and state that "the toxicity of neutral sulphites is a legend." On the other hand, both Lange and Gruber object to the use of sulphites on sanitary and hygienic grounds. In a similar manner, Tunnicliffe and Rosenheim proved to their own satisfaction that neither boric acid nor formaldehyde exerts a harmful action upon healthy children, while Kister, in a very carefully conducted research, arrives at an opinion diametrically opposed. I could go farther, and cite other examples but without finally settling the question in dispute. Enough has been said, however, to indicate the prevailing difference of opinion. In spite of the large amount of work which has been bestowed upon this subject, the discussion and experimentation have hardly passed beyond the academic or theoretical stage, and there is great need for the more practical demonstration before we accept the use of these substances as harmless. I believe it to be wise to regard every chemical preservative as guilty until proved innocent. A little thought will show how difficult accurate, reliable experimentation must be in this matter, for a living body is a far more variable reagent than a chemical solution and, moreover, different individuals or animals must of necessity react differently according to their state of health, powers of digestion, occupations, and so forth. Thus it will be necessary to make many observations before the matter can be settled.

It is true that there is a class of foods such as ham, bacon, dairy products, jams, etc., of such character that their flavor or usefulness would be destroyed by heat. For these harmless preservatives would be of special value, and use of preservatives in such foods has some slight excuse on the grounds that the antiseptic is necessary to prevent decomposition. In such cases every package should be plainly labelled with the name of antiseptic it contains. In canned goods, on the other hand, the use of any antiseptic should be unhesitatingly condemned, for it is absolutely unnecessary if the food has been properly prepared and sterilized. Addition of any preservative to canned foods is a virtual acknowledgment that the packer does not know his business, and the use of such substances can only be

regarded as a makeshift to cover up slovenly, uncleanly, and inefficient methods. The absence of preservatives in canned goods is an indication of good, intelligent management, cleanly methods, and wholesome food, as a rule. Their presence shows the reverse characteristics, for if a manufacturer depends upon the use of a preservative to ensure the keeping quality of his goods, he is putting a premium upon inefficient and careless work.

Whether preservatives are ultimately proved to be injurious or otherwise, their use in canned goods should never be allowed, for the simple reason that they are unnecessary if the goods have been properly prepared.

In the different states there are numerous laws regulating the use of these chemical antiseptics in foods. As these laws are different, a man might conceivably be acting within his rights in one state and violating the law by selling his product in another. At the present time the only way to be sure of being on the right side is by abstaining entirely from the use of antiseptics, for here as in all things else, total abstinence is the only *absolutely* safe method of keeping out of danger.

It is probable that their use cannot be at present entirely prevented. Consequently a national law regulating the use and restricting abuse of such substances is most to be desired. That this subject is of international or universal interest is made evident by the amount of discussion which has been given to it in England and on the Continent. The latest contribution is in the recently published report of the Committee appointed by the British Government to investigate the use of preservatives and coloring matters in foods. The report of the Committee is, on the whole, unfavorable to the use of preservatives. It recommends that the use of all preparations of formaldehyde, or formalin, in foods or drinks should be absolutely prohibited, and that salicylic acid be not used in greater proportion than one gram per pint in liquid foods or one gram per pound in solid food — its presence in all cases to be declared. The report further recommends that the use of any preservative or coloring matter in milk should constitute an offence; and that for preservation of cream, butter, and margarine only boric acid or mixtures of boric acid and borax should be used. The amount of antiseptics should not exceed 0.25 per cent., expressed as boric acid, in cream, or 0.5 per cent. in butter or margarine. It is interesting to note that the report insists

that no preservative of any kind should be used in any dietetic preparation intended for the use of infants or invalids, and also opposes the use of copper salts in "greening" of vegetables, although one member of the Committee demurred in this judgment. Comment upon this excellent report is almost unnecessary, except to say that it emphasizes anew the unsettled state of the question and the necessity for much further experimentation before anything like a final verdict can be pronounced.

The prohibition of the use of preservatives in foods designed especially for infants and invalids betokens some suspicion on the part of the Committee that there is no chemical antiseptic which is not objectionable under some circumstances.

In conclusion, let me reaffirm the necessity for more information upon this important subject. I believe it would be wise for such bodies as this association to take whatever steps may be within their power towards further investigation, either by agitation for a national court of inquiry similar to that recommended by the English report, or otherwise. The Agricultural Department at Washington has already done much in this direction, but more could be done if the manufacturers of preserved foods would show a spirit of something more than selfish interest, and use their power to further the work. In my opinion, such action on their part would be fully repaid, even in a financial way. And especially let me emphasize again that the two best agents for preservation of foods that are at our disposal are cold and heat; cold for the fresh foods which are to be kept temporarily, and heat for that greater and ever-increasing class of canned foods which can be kept for any length of time and in all climates, and which already play so important a part in the nutrition of the world. If the producers of canned foods are wise, they will endeavor to secure complete sterilization by heat, cleanliness, rapidity and economy of production, and intelligent, scientific management of their factories. They will thus have no use for preservatives, but will regard them as undesirable not only because unnecessary, but also because there is no valid reason for the addition to what must otherwise be regarded as pure foods, of substances of dubious effect upon the health of the consumer.

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CORROSION OF THE STEEL FRAMES OF BUILDINGS.

By CHARLES L. NORTON.

The constantly increasing use of steel as a structural member in modern buildings has led to many questions as to the permanency of the steel as sometimes used for this purpose. The examination of buildings ten to fifteen years old, when, during alterations, the steel framework has been exposed to view, reveals all stages and conditions of disintegration of the steel. So great has been the corrosion, even in this short time, in some cases, that a note of alarm has been sounded by some engineers most familiar with the subject. The use of steel beams and posts is of so recent date that no very exact deduction can be drawn as to the exact time required for a very serious or destructive loss of steel through corrosion; but surely, when a steel plate one-half inch in thickness loses more than one-eighth of an inch in five years, there arises a question as to the ability of the structure to last more than twenty-five years.

Some of the factors in the matter of corrosion of the steel we know; others we do not know, and cannot until after a lapse of some years.

There can be no question that moisture and carbon dioxide are the active agents in causing much of the rusting of the steel. To what an extent the two are relatively responsible and in what measure they need renewal, to keep up the process, is uncertain. It has been held that the formation of a coat of rust upon the surface of steel was the beginning of a progressive action whereby the rust, or iron oxide, acted as a continuous carrier of oxygen to the steel beneath. This process seems to require only moisture and atmospheric air containing carbon dioxide to start it, but as to the depth of penetration of the process I know of no assignable maximum in any given time. It is extremely probable that in a comparatively dry place the process is exceedingly slow.

There can, of course, be no question, in many cases, as to the ease of access to the steel of both moisture and carbon dioxide.

When steel is bedded in the wall of the building, as is almost always the case, the changes in temperature from time to time, as well as the more or less constant difference in temperature between the two faces of the wall, tend to cause a condensation of moisture in the wall at different points. Further, the necessary carbon dioxide is most plentiful in the large cities, where the steel frame is most common.

When the walls of the building are of brick or stone, moisture and carbon dioxide may usually enter at the joints and, to a greater or less extent, through the body of the stone or brick. Few stones are, however, porous to such an extent as to allow an appreciable penetration. Terra-cotta tile is of itself porous, and the existence of air passages tends to increase the condensation of moisture and absorption by the terra-cotta and possible contact with the steel. Concrete, made of Portland cement with sand and either cinders or stone, would seem to offer more protection to the steel than any of the materials just mentioned; yet, we hear from time to time of the loss, by corrosion, of steel bedded in concrete.

A study of the action of Portland cement concrete on steel was begun under my direction by Mr. P. C. Pearson in December, 1901, and it is my purpose to report upon this and some later observations as a preliminary to more work of the same nature now under way.

It has been held by several engineers that the mere alkaline nature of Portland cement was a sufficient guarantee of its protecting steel from rusting. There is, of course, good chemical reasoning for this, the familiar use of strong alkaline solution in boilers to prevent the formation of scale being based upon the same principle. This would seem to settle the matter once and for all, were it not a fact that steel bedded in concrete has corroded very rapidly, while other steel in a different concrete of the same kind of cement stands without change for ten years or more.

The investigation was started, not to find out that steel could not be protected by concrete or that it could be, for on that point we were sure, to start with, but we have tried to find a reason for occasional failure and to suggest a remedy.

An examination of several cases where expanded metal had been embedded in concrete showed plainly that wherever the steel was exposed through cracking, rusting began, even though the cracks were very fine. It would seem that the alkaline nature of the cement would

be sufficient to prevent corrosive action occurring within a few hundredths of an inch on the moist surface of the steel, but such is not always the case.

To study the matter systematically, two brands of American Portland cement (*Alpha* and *Lehigh*) were selected; two kinds of cinders, one from the Sugar Refinery, the other from the Boston and Albany locomotives; a sharp, clean beach sand; and a hard, clean broken stone, the larger part being fragments of flint and trap rock. Concretes were made up in bricks about 3″ x 3″ x 8″, with the steel specimens near the centre.

The following mixtures were tried at first; others will be reported on later: Neat cement; cement, one part, to three of sand; one part of cement and five parts of broken stone; and one part of cement to seven parts of cinders. All briquettes were made in duplicate with both cements. There were later made up briquettes of one part of cement to two parts of sand and five parts of cinders, and of one part cement to two of sand and five of crushed stone. The table below gives a summary of the mixtures: —

Alpha Cement.	Lehigh Cement.	Sand.	Stone.	Cinders.
1	0	0	0	0
0	1	0	0	0
1	0	3	0	0
0	1	3	0	0
1	0	0	5	0
0	1	0	5	0
1	0	2	5	0
0	1	2	5	0
1	0	0	0	7
0	1	0	0	7
1	0	2	0	7
0	1	2	0	7

It was hoped to vary the density, the porosity and the nature of the contact with the steel, as well as the chemical composition of the concretes. The cements were tested chemically and physically and found good. The cinders, when washed down with a hose stream and dried, tested distinctly alkaline, and analysis revealed very small amounts of sulphur. The stone and sand were thoroughly washed and clean. The ingredients were mixed dry in every case and, when wet, thoroughly mixed and tamped until wet on top.

The cleaning of the steel was the most troublesome problem met

with. It was necessary to scour the pieces, then pickle in hot dilute sulphuric acid, and finally dip into hot milk of lime. When cold, the lime was removed with a wire brush. This left the steel clean and bright, ready to be put into the test bricks.

The specimens used were a mild steel rod 6″ long and $\frac{1}{4}$″ in diameter, a piece of soft sheet steel 6″ x 1″ x $\frac{1}{32}$″, and a strip of expanded metal 6″ x 1″, all three pieces being put in each brick. Since time would not permit of our exposing these specimens to natural conditions, we enclosed them in several large tin boxes, sealed tightly,

FIG. 1. — STEEL PROTECTED BY CEMENT.

and subjected one quarter of them to an atmosphere of steam, air and carbon dioxide, and second quarter to air and steam, a third to air and carbon dioxide, and a fourth stood upon the table of the room, with no special care as to their temperature or dryness. Of the entire number, about one-half were set in water for one day, the rest for seven days, before sealing up.

At the end of three weeks the briquettes were carefully cut open and the steel examined and compared with specimens which had lain unprotected in each of the tin boxes.

Those specimens which were mixed of neat cement can be dismissed without discussion, for the protection was perfect. The steel was as bright as when put in. (Figure 1, Nos. 25, 26, 84, 68.)

The unprotected pieces were found to consist of rather more rust than steel. The steel was wrapped about pieces of uralite, to serve as a means of identifying it by number, the stamped numbers being nearly obliterated by the rust.

FIG. 2. — STEEL RUSTED BY CONTACT WITH CINDERS.

Of the remaining specimens, hardly one had escaped serious corrosion. The location of the rust spot was invariably coincident with either a void in the concrete or a badly rusted cinder.

In the more porous mixtures, the steel was spotted with alternate bright and badly rusted areas, each clearly defined. In both the solid and the porous cinder concretes, many rust spots were found, except where the concrete had been mixed very wet, in which case the watery

cement had coated nearly the whole of the steel, like a paint, and protected it.

Some briquettes made later of finely ground cinders and cement, in varying proportions, when exposed to moisture and carbonic acid, showed how effectually the presence of cement prevented rusting, even in a highly porous mass, — one cement to ten of cinder, provided there were no cracks, or crevices, or distinct voids.

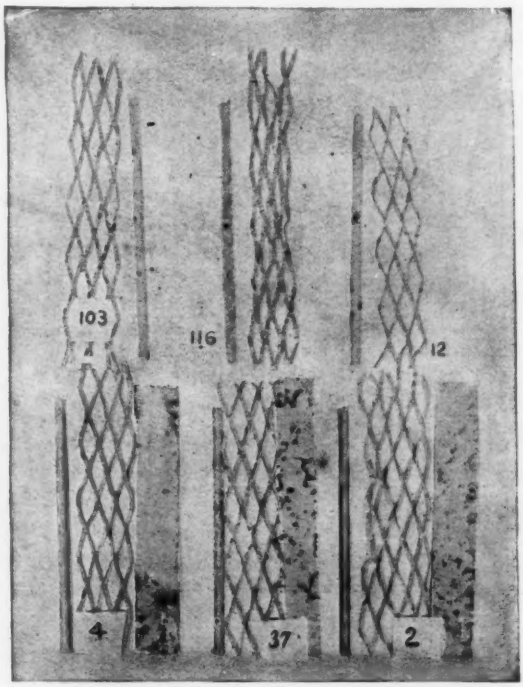

FIG. 3. — STEEL RUSTED AT VOIDS IN CONCRETE.

From the examination of these several hundred briquettes we were able to draw several conclusions: —

First. Neat Portland cement, even in thin layers, is an effective preventive of rusting.

Second. Concretes, to be effective in preventing rust, must be dense and without voids or cracks. They should be mixed quite wet where applied to the metal.

Third. The corrosion found in cinder concrete is mainly due to the iron oxide, or rust, in the cinders and *not* to the sulphur.

Fourth. Cinder concrete, if free from voids and well rammed when wet, is about as effective as stone concrete in protecting steel.

Fifth. It is of the utmost importance that the steel be clean when bedded in concrete. Scraping, pickling, a sand blast and lime should be used, if necessary, to have the metal clean when built into a wall.

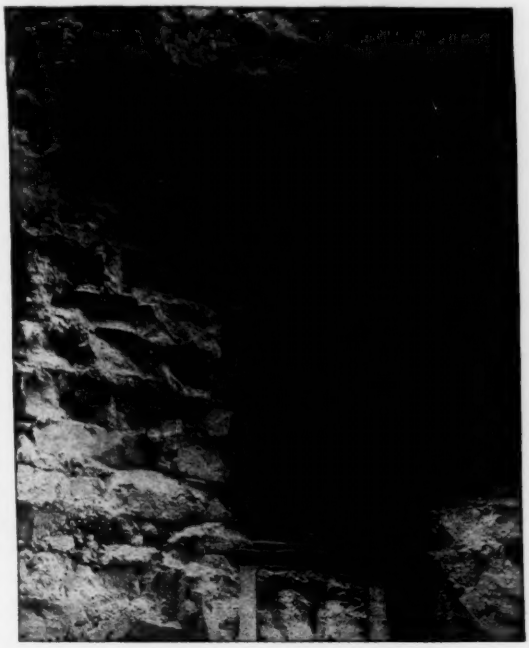

FIG. 4. — PAINTED STEEL IN BRICKWORK. FIVE YEARS OLD.

In the matter of paints for steel, there is a wide difference of opinion. I cannot believe that any of the paints of which I have any knowledge can compare with a wash or painting with cement. Moreover, if paint does disintegrate, it leaves a thin void next the steel, the worst possible condition. I examined some steel Z-bars not long ago, which were exposed in process of altering a building five years old. It was clear that the steel was rusty when painted and that moisture had penetrated through the paint, caused the rust to increase

and split off the paint. This was a case where the steel was built into the brickwork with no attempt at any protection other than the paint.

It is, in my opinion, perfectly clear that the coating of all steelwork with cement before applying the concrete or tile or brick, as the case may be, is an absolute essential, if the formation of rust and consequent weakening of the steel is to be prevented. The thickness of the cement layer need not be great, but it should be a continuous coating, without cracks. The steel should be perfectly clean; but if, as is often the case, the choice is between paint and rust which accumulates during construction, the paint is to be preferred.

Mr. Pearson suggested the use of Portland cement in protecting the under side of railroad bridges against rust and the blasting action of the gases and cinders from locomotives. I think this merits a careful trial.

It is intended to take up the study of paints as a protection for steel, and to study, as well, the action of corrosion with long lapses of time in the walls and buildings of the Experiment Station now about to be erected. The first fire-testing work will also be upon the tile, brick and concrete protection of steel from fire. Next we propose to study the effectiveness of the many kinds of "finish" for buildings. A small, two-story house of refractory material, into which the finish to be tested can be built, is needed for this work, and already several materials are waiting to be tested. The kiln for testing floor spans, beams, and posts is to be about fifteen by twenty feet, and it will be heated by a battery of oil burners well above the melting-point of cast iron.

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ALUM IN WATER.

A. H. Low's Modification of the Logwood Test.

By ELLEN H. RICHARDS.

In Volume 4 (1891, p. 194) of this journal, a method was described for detecting alum in water by the use of a freshly prepared solution of logwood.

With the increasing use of mechanical filters the test has become of an importance little dreamed of at the time. Various workers have spoken for and against the method. Professor J. W. Mallet, of the University of Virginia, suggested in 1899 the use of hæmatoxylin, which now may be had of considerable purity — by which one part of alum in 5,000,000 could be detected.

As early as 1898, Mr. A. H. Low (M. I. T. 1876), of Von Schulz & Low, Denver, Colorado, having occasion to test the effluent from the mechanical filters of the Denver Union Water Company, began experimenting with the logwood test with especial reference to the interfering substances.

At that time one part in 4,000,000 was his claim for the test.

Mr. Low has continued his experiments and has given his permission for the publication of his method, which appears to be a distinct contribution to the accuracy and delicacy of the determination, since one part in 8,000,000 may be detected. The exclusion of carbon dioxide up to a certain stage in the process, when it is required, and the prevention of access of alkali from glass vessels by the use of platinum are essential points.

Mr. Low has kindly supplied the following directions: —

Directions for the Alum Test. — The logwood solution is made as follows: Take two grams of logwood chips and boil one minute in a platinum dish with 50 c.c. of distilled water. Decant the solution and boil again for one minute with 50 c.c. of water. Decant this and similarly boil a third time with 50 c.c. of water. Decant this into a plati-

num receptacle for use. Take three drops for each test. Kept in platinum, the solution will last for several days at least.

Test the water as follows: Boil 50 c.c. of the water in a platinum dish for a short time to expel carbon dioxide. Add three drops of the logwood solution and continue boiling for a few seconds to develop the color. Decant into a glass flask and cool quickly under the tap (so as not to keep the hot solution too long in the glass). Transfer to a No. 2 beaker and blow in carbon dioxide from the breath by means of a glass tube until there is no further decolorization. Pour the water into a Nessler tube for comparison with standards similarly prepared. Allow them to stand several hours before taking the final reading. No wash water is used at any of the decantations. The test shows one part of aluminum sulphate in 8,000,000 parts of water.

A blank made with distilled water, if not completely decolorized by the CO_2, will show a tint perceptibly fainter than that produced by one part in 8,000,000 of aluminum sulphate.

It should be noted that carbon dioxide must be kept absent until the point prescribed. The solution is therefore transferred to a beaker in order to keep the flask free from carbon dioxide for the next test.

The main points are:—

1. Any kind of logwood appears to answer.
2. The solution is good for several days, at least, if kept in platinum.
3. The use of platinum instead of glass for boiling the test.
4. The use of carbon dioxide instead of acetic acid.

Aluminum hydrate, as pointed out by the late Professor A. R. Leeds in 1893, will produce a tint almost as strong as if it were in solution. The removal of the hydrate is a difficult matter.

Mr. Low's method of procedure is as follows: first, test the water as above described. If no tint, or none exceeding that of the blank, remains after standing several hours, or over night, that is sufficient. If, however, a tint persists, or a colored precipitate settles out, it is necessary to determine if this is due to aluminum hydrate. Pour a sample of the water several times through a double Swedish filter and finally test the filtrate. If the tint produced is weaker than that given by the unfiltered water, repeat the operation on a fresh portion of the water, using the same filter, and continue repeating with new portions of the water and always using the same filter, until it is apparent that no further diminution of the tint can be effected. The

tint finally remaining may be assumed to be due to a salt of aluminum in solution.

An alternative method is to clog a filter with a little aluminum hydrate, wash until no test is given, and then filter the sample of water. The writer does not agree with Mr. Low's suggestion to allow the filtered water to stand several hours and then refilter. The filtrate from a mechanical filter which uses alum should be tested at once. A slow decomposition appears to take place by which aluminum hydrate separates out. While it may be said that consumers do not use the water until after the lapse of some hours, the chemist should be able to say whether any undecomposed alum comes through the filter.

Mr. Low gives the following directions for the use of hæmatoxylin:

Dissolve 25 mg. in 25 c.c. of warmed water. Add one drop to 50 c.c. of the water to be tested, boil in a platinum dish until the color appears to be fully developed — about thirty seconds. Pour into a flask, cool under the tap. Blow carbon dioxide from the breath through the solution so long as any color due to alkali seems to be discharged.

SOME NOTES ON SEVERAL TYPES OF MANTLES FOR INCANDESCENT GAS BURNERS.

By WILLIAM LINCOLN SMITH, S.B.

Received November 14, 1902.

Some nine or ten months ago I had occasion to make use of a number of mantles for incandescent gas burners and, as it fitted in with some other work which I had on hand, I made a series of tests upon a number of styles of mantles on the market in Boston with a view to the determination of their characteristics. In addition I made some tests upon a number of tinted chimneys and globes for use with the mantle.

The results which were obtained were partially presented in the spring at one of the local scientific clubs and are embodied rather more fully in the following account of the work, which I may say makes no claim to be exhaustive.

The instruments used were a Weber Portable Photometer, made by Krüss, and a König Spectrophotometer, loaned me by Professor Cross of the Department of Physics (through whose kindness I was further enabled to do a considerable portion of the work in one of the dark rooms of this department of the Institute). The gas supply was taken from the city mains, metered by a 3-light Wet Test Meter, and the pressure was controlled by a regulator kindly loaned me by Dr. Gill of the Chemical Department.

Ten types of mantles were examined, which are numbered consecutively from 1 to 10 in the tables and on the plots. I only give the names of the three types which I finally chose for complete study. These were: 1st, The Yusea. 2d, The Majestic, and 3d, The Admiral. All of the mantles were purchased of retail dealers at various times without any suggestion as to the use to be made of them, and six of each were tested, the results here given being in each case the mean of the six specimens. Very slight changes in position of the mantle on the burner were found to make exceedingly large variations in

the photometer reading, due to the varying amount of net on the rear side of the mantle which showed through the meshes on the side toward the photometer. I found that the individual mantles of a given type were hardly near enough alike to allow of any general method of correcting for this, and accordingly obtained a burner for each type of mantle which could be slipped over the free end of a fixed pipe and brought definitely to a fixed position by cross hairs in a small telescope and a gauge mark on each burner. In order to locate the mantle properly at first, I adjusted the burner for maximum candle-power as shown on the photometer, and then turned the burner on the pipe until the photometer gave the highest possible reading. Then by means of a lens I projected an image of the mantle on a sheet of cardboard, tacked on the wall behind the photometer, and drew out with ink the outline of a large section of the mesh as it appeared in the image. When a second mantle of similar type was to be used, it was placed on the burner and turned so that the image of its mesh coincided as nearly as might be with that lined out upon the cardboard.

With a given type of mantle tests were first made to determine the change in candle-power for different rates of consumption of gas; then the mean of the six sets were determined, and the two mantles which came nearest to this mean were selected for further examination. These two were then compared with the spectrophotometer at fifteen equidistant points from $\lambda = 7750$ to $\lambda = 4250$ inclusive, and if the ratio between the two mantles appeared irregular, another mantle was compared also. Two mantles as nearly similar as might be having been found, they were laid aside for further study.

The Instruments.

Weber Photometer. — This instrument was used with a small incandescent lamp as a secondary standard. It was run from a portable storage battery (kept steadily charged by a battery of gravity cells), and in circuit with it was placed a small finely divided rheostat, so that the voltage applied to the lamp as indicated by a Weston voltmeter could be carefully adjusted and held constant within very narrow limits. This secondary standard had been carefully checked against an amyl-acetate lamp. It was found possible to do all the work required of this instrument, while making use of only two com-

binations of diffusing plates in the photometer box, and keeping the lamp under test at a fixed distance of 730 mm. from the instrument. These two combinations were: for the feebler candle-powers, Plate 4 alone, and for the stronger candle-powers, Plates 8, 6 and 4 together. The formula for the candle-power of a light at a distance R from the diffusing plate is $I = \frac{R^2}{r^2}C$ where r is the scale reading of the instrument when balance is obtained, and C, a constant depending on the secondary standard used and the diffusing plate inserted in the instrument at the time.

Since the secondary standard was not changed and the value of R remained fixed at 730 mm., two constants were found — C' when Plate 4 was used, and C'' when Plates 8, 6 and 4 were used, the value of R^2 being combined with C in the above formula.

These constants were:—

$$C': \text{Log} = 5.2988$$
$$C'': \text{Log} = 6.2053$$

It was then in any particular case simply necessary to subtract from the Log C' (or C''), the Log of r^2, when the corresponding candle-power was at once obtained.

In fact, however, the procedure was a bit more complex because of the difference in color between the secondary standard and the lamp under test. This type of Photometer is fitted with two extra eye diaphragms, one of red and the other of green glass, the particular hue of the glass being carefully chosen. Suppose the candle-power of a light is measured through the green glass and found to be Gr, similarly through the red glass it is found to be R, we find the ratio $\frac{Gr}{R}$; look up in a table supplied with the instrument, a factor k corresponding to this ratio, and the product kR is the true value of the candle-power required.

It may be of interest to see how a result thus obtained will check the spectrophotometer: thus I measured the candle-power of a certain mantle covered with a thin, white, opal globe and found it to be 59.4 candles; when covered with a similar pink opal globe the candle-power was 43.2, the loss of light being 27.3%: $\left(\frac{59.4 - 43.2}{59.4}\right)$

I then found with the spectrophotometer the curve (A) of ratio of intensity at different wave lengths of the white shaded mantle to the naked mantle, and the similar curve (B) for the pink shaded mantle to the naked mantle. By planimetering, the mean ordinate of curve A was found to be 148.2 units, and that of curve B was found to be 104.5 units, the loss according to these values being $\left(\frac{148.2 - 104.5}{148.2}\right)$ or 29.5 %, as compared with 27.3% above. I should say that this test was not made for a close check, but I was curious to see how close one could come in ordinary rapid work without any special precaution. Probably if the spectrophotometer readings had been extended over a wider range, the check would have been closer.

Spectrophotometer.— The results obtained with this instrument are purely relative, the figures given being invariably a ratio between the light under test and a specified standard. These results are fully as instructive for the purpose at hand as absolute values would be, while in view of the absence of any definite standard for such purposes and of the difficulty of getting the results on an absolute basis (say of energy), it was deemed best to leave them simply as ratios.

The constant of the instrument was determined as follows: The ratio between the two lights is $i = k \tan^2\phi$ where ϕ is the angle through which the Nicol prism in the eyepiece must be turned from its zero position in order that the two halves of the field may be of equal brilliancy, while k is a constant arising from the inequality to the two different light paths through the instrument.

The two halves of the field being illuminated by monochromatic light from the same source (a sodium flame screened with very uniform milk glass), the zero of the Nicol (for maximum darkness of the upper field) was found to be $\theta = 2^\circ\ 1'\ 18''$. Again the setting for equal brilliancy of the two halves of the field was $\theta' = 49^\circ\ 43'\ 0''$. Now it may be shown that $k = \text{cotan}^2\ (\theta' - \theta)$, so that we have

$$k = 0.8286. \quad \text{Log}k = 9.9183 - 10.$$

The next step was the calibration of the scale of the instrument in wave-lengths. The Nicol eyepiece was removed and replaced by one which simply gave an image of the slit as in the ordinary spectroscope. The slit was illuminated with light of the desired wave-length, the line brought to the middle of the field and the corresponding scale reading observed.

In this way the following calibration was obtained:

TABLE 1.

LINE.	WAVE-LENGTH.	SCALE READING.
K_α	7680	11.53
Li	6708	12.05
H_α	6563	12.15
Na	5893	12 68
Tl	5349	13.29
H_β	4861	14.06
H_γ	4341	15.30
K_β	4046	16 31

The curve shown in Figure 1 was then plotted from these data and from this curve the points given in Table 2 were determined, these being the points at which measurements were made throughout the remainder of the work.

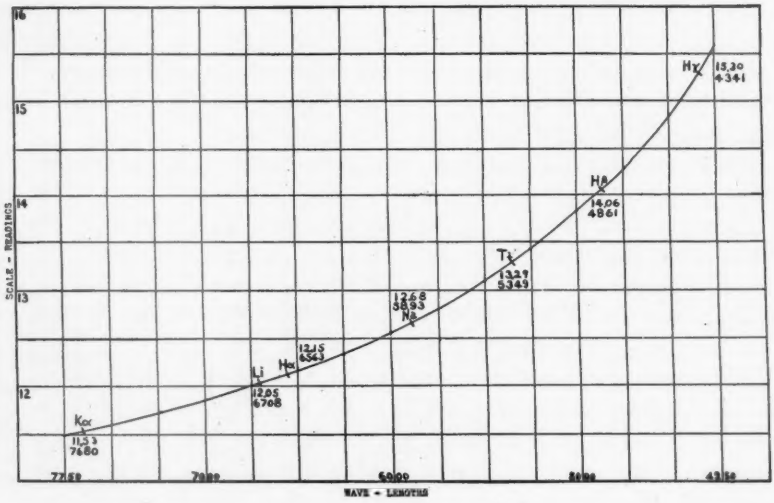

FIG. 1.

TABLE 2.

WAVE-LENGTH.	SCALE READING.	WAVE-LENGTH.	SCALE READING.
7750	11.49	5750	12.81
7500	11.62	5500	13.10
7250	11.75	5250	13.43
7000	11.88	5000	13.82
6750	12.03	4750	14.29
6500	12.19	4500	14.86
6250	12.37	4250	15.59
6000	12.57		

Gas Meter. — This was of the usual round pattern of wet meter, rated for 3 lights, as made by the Nathaniel Tufts Company. It was carefully calibrated by comparison with a number of large bottles whose volume was known. A volume of 20.46 cubic feet of gas, as measured by the bottles, was passed through the meter, which recorded 20.45 cubic feet. The meter was accordingly assumed correct within any limits required in this work.

RESULTS OF CANDLE-POWER TESTS.

The following Table 3 gives the gas consumption in cubic feet per hour, and corresponding candle-power of the mantles tested, together with an Argand and common flat flame burner, which are inserted for comparison:

TABLE 3.

ARGAND.		FLAT FLAME.		MANTLE NO. 1. YUSEA.		MANTLE NO 2. MAJESTIC.		MANTLE NO. 3. ADMIRAL.		MANTLE NO. 4.	
GAS.	C. P.	GAS.	C. P.	GAS.	C. P.	GAS.	C. P	GAS.	C. P.	GAS.	C. P.
2.01	2 02	.93	2 54	1.25	3.30	1.41	2 18	1.80	2.19	1.20	2.20
2.37	3.58	1.50	4 64	1.75	33.20	1.95	7.31	1.98	4.30	1.44	3.26
2.64	4.54	2.22	7.31	2.05	49.50	2 37	22 00	2.22	17.70	2.04	9.59
2.85	5.93	3.00	9.33	2.45	68 90	2 55	38.90	2.64	37.80	2.49	24.50
3.27	8.06	4.02	11.80	2.85	80 50	2.79	57.50	3.00	51.20	3.23	56.20
3.72	16.70	5.34	12.70	3.20	86.00	3.72	85.00	3 78	79.50	3.84	75.20
4.53	22 00	6.18	11.60	4.00	78.50	4.32	76.30	5.16	67.70	4.98	66.80
5.70	26 70	6.90	11.40	4.85	67.00	5.04	68,50	5.82	60.40	5.70	54.90
5.82	30.30	7.68	11.20	5.85	59.50	5 82	60.40	6.30	57.50	6.36	45.90
6.78	33.10			6.53	56 60	6 36	57.50	6.60	56 20	6.96	41.30
6.96	36.40			7.44	55.50	6.96	55.50	6.96	51.20		
7.53	38.20										
7.92	40.10										
8.70	42.20										
9.00	43 10										
10.20	44.40										

Mantle No. 5.		Mantle No. 6.		Mantle No. 7.		Mantle No. 8.		Mantle No. 9.		Mantle No. 10.	
Gas.	C. P.	Gas.	C. P.	Gas.	C. P.	Gas.	C. P.	Gas.	C. P.	Gas.	C. P.
1.62	2.40	1.65	2.07	1.77	3.76	1.42	2.07	1.50	2.07	1.20	2.30
1.92	5.46	1.77	3.79	2.16	12.30	1.74	5.13	1.71	6.50	1.38	3.45
2.22	11.80	1.95	11.80	2.46	41.30	1.98	10.80	2.04	16.40	1.53	9.21
2.82	35.40	2.28	38.20	3.00	54.30	2.10	18.80	2.46	39.30	1.86	16.90
3.12	46.40	2.58	44.40	3.39	55.60	2.46	32.60	2.73	57.50	2.28	37.40
3.72	62.70	3.00	62.70	3.45	54.20	3.00	55.50	3.61	61.90	2.73	55.50
4.08	72.30	3.90	49.50	3.72	49.50	3.96	61.90	4.11	54.90	3.78	61.10
4.50	65.10	4.77	39.30	4.74	38.20	4.20	53.00	4.43	42.20	4.56	49.00
4.98	60.40	5.76	31.20	5.70	31.70	5.34	46.90	5.82	37.10	5.28	45.90
5.28	56.90	6.75	28.80	6.78	28.30	6.42	40.10	6.96	36.40	5.94	42.60
5.70	51.20			7.50	27.40	7.14	38.20			6.96	35.50

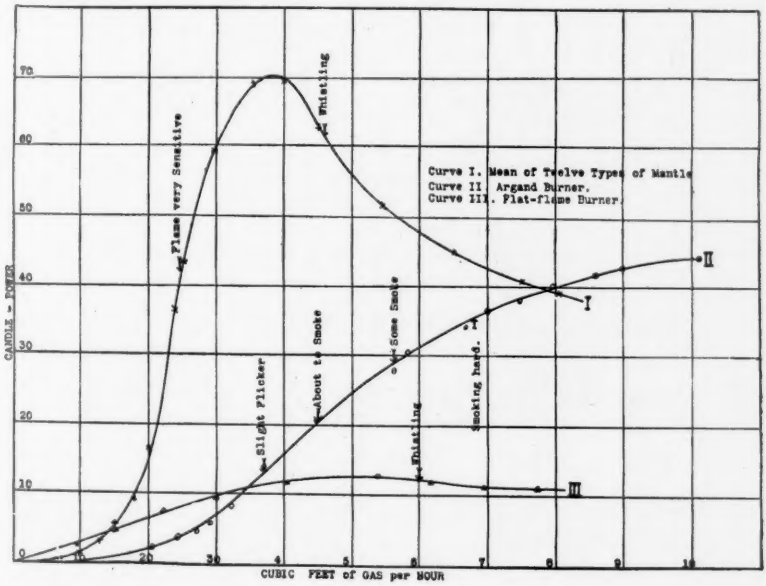

FIG. 2.

The same facts are shown in Figures 2, 3 and 4. Figure 2 shows the curve of the Argand, the flat flame, and the mean of the ten types of mantle. Figures 3 and 4 show the curves for the individual types. It is interesting to notice how the mantles separate into two groups

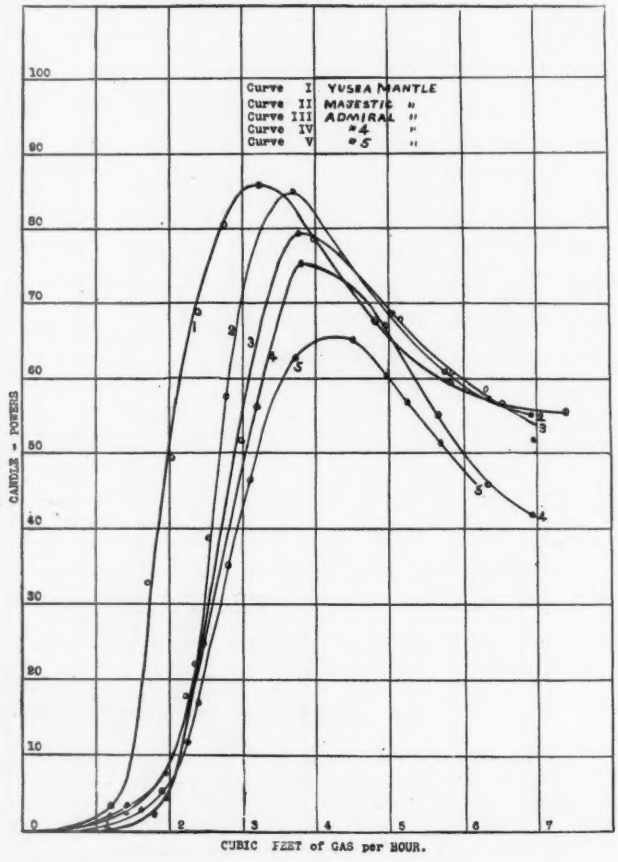

FIG. 3.

of five each, one having an average maximum of about 75, the other of about 60. This does not connect with either make, price, size of mesh, or number of threads — it may be due to correspondence in composition, but nothing appeared on the spectrophotometer to indi-

cate it, and I am unable to say at present that it is more than a coincidence.

It should be said that all of the mantles showed an increasing tendency with age to clog up with soot, some more rapidly than

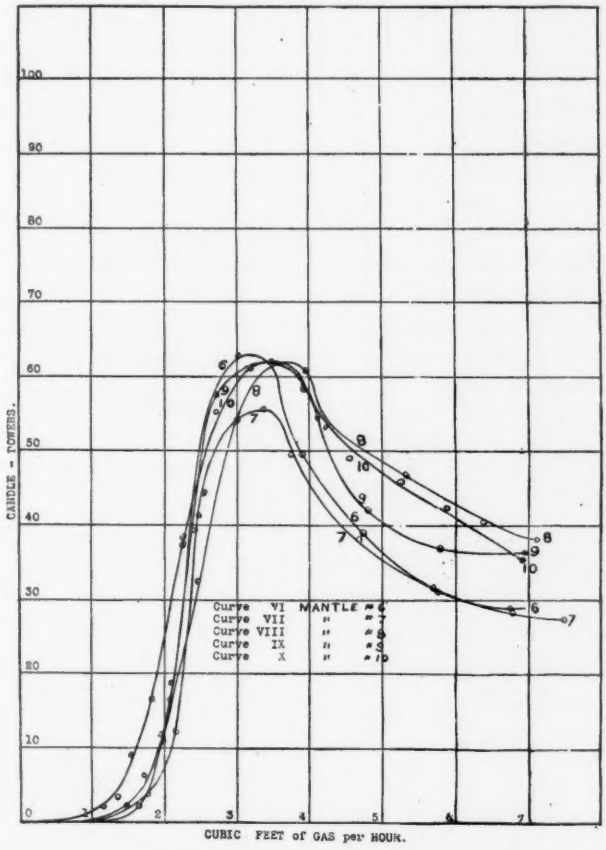

FIG. 4.

others, however. In the matter of handling, which of course is deleterious in the extreme after the mantle is once lighted, the Yusea and the Admiral seemed by far the most durable. Again, the matter of warping is an important point, and here the Yusea and Majestic led, with the Admiral a good third.

It may be also of interest to note that the flame invariably passed through a very sensitive state, so much so that frequently a sharp snap of the thumb and finger or a sneeze across the room would nearly or completely extinguish the light, and that this point occurred invariably when about three-quarters of the way up the steep ascent of the curve toward maximum brilliancy, which was reached shortly after the sensitiveness had fallen off, while about an equal distance beyond the maximum on the descending branch of the curve occurred the "whistling point," where the gas began to make a noticeable noise as it passed the burner.

The examination thus far seemed to show that the choice lay between the three mantles already named, with a possibility of Number 4 also, but this latter seemed very fragile and clogged badly, so that I finally discarded it; the other three were fully tested, with results now to be described.

Table 4 and Figure 5 show the results of the test for gas consumption and candle-power for the three selected mantles at the end of a 200 hours' life test.

TABLE 4.

Yusea Mantle.		Majestic Mantle.		Admiral Mantle.	
Gas.	C. P.	Gas.	C. P.	Gas.	C. P.
0.85	1 90	0.80	1.00	1.15	.60
1.36	10 50	1.28	2.10	1.70	7.00
1.90	33.20	1.80	16.20	2 20	17.80
2.54	60.40	2 45	37.80	2.50	31.00
3 25	69.30	3 22	61.50	3.00	49.20
3.87	68 00	3 90	62.50	3.60	57.80
4.53	64 10	4.50	54 20	4 28	55.50
5.20	58.50	5.15	46 50	5 12	48.80
5.74	55 00	5.68	41.50	5.60	43.50
6.22	54.20	6.17	40.50	6.10	39.00

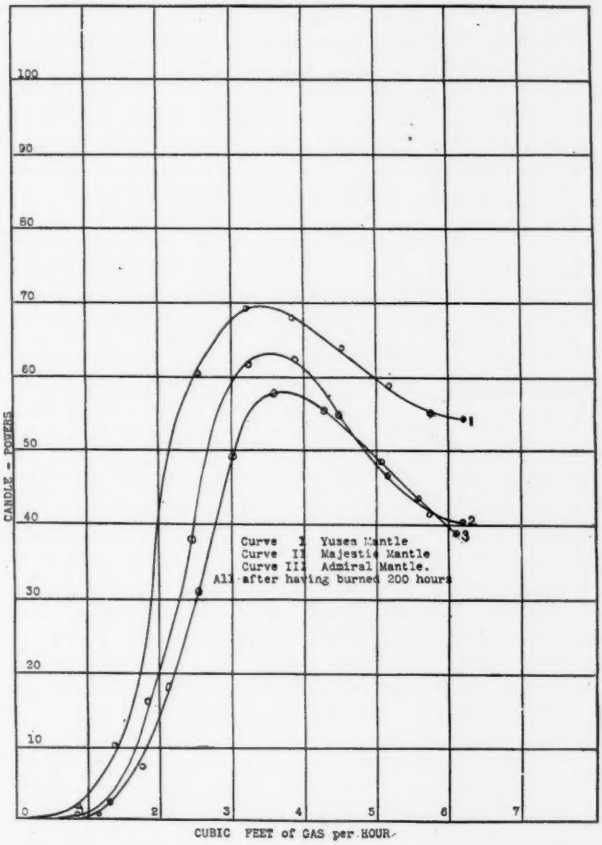

FIG. 5.

It is well known that mantles, though they may give a very white light at first, immediately begin to change in color, some more rapidly than others and some going further than others in the direction of a sickly greenish hue, which is exceedingly disagreeable, the majority tending toward a hue on the blue side of the green, but some toward one on the yellow side. The only way of telling what and how great change takes place is to study the mantle throughout a lengthy period with the spectrophotometer.

The plan followed was to take the two matched mantles selected as previously described, and having chosen one as a standard, to place it in position and adjust the burner and cocks in the piping so that after having warmed up, it consumed gas at the proper rate. This mantle was burned as little as possible — in all a total of less than four hours.

The other, or test, mantle was put in position and burned steadily for 200 hours. It was compared with the standard after having burned 5, 10, 20, 40, 50, 80, 100, 120, 140, 160, 180, and 200 hours; at

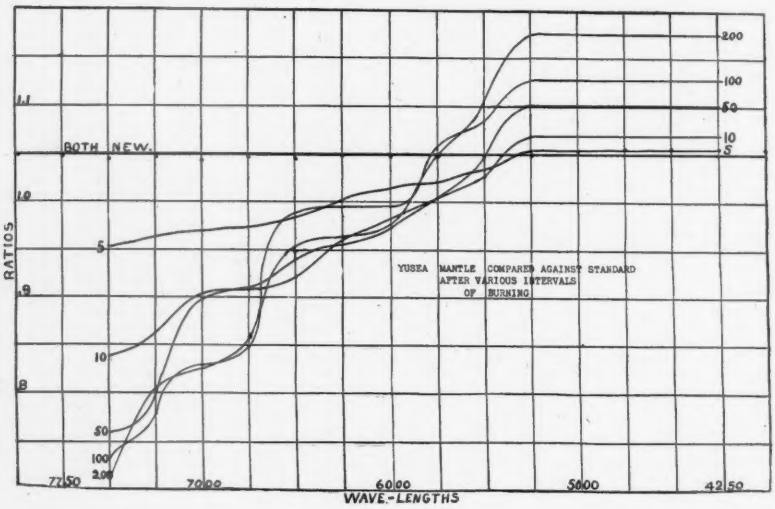

FIG. 6.

these times it was also tested for candle-power at the rate of gas consumption which the previous test had shown to give the maximum light, and at the end of the 200 hours it was again examined for candle-power with changing gas consumption, for comparison with the measurements made when it was new.

Of course it should be noted that the standard mantle itself changes somewhat, and that accordingly the curves are not exactly what they would be if it remained constant; however, I examined one mantle pretty carefully, and came to the conclusion that it was hardly worth while to attempt to correct for this change, as its effects were not very marked.

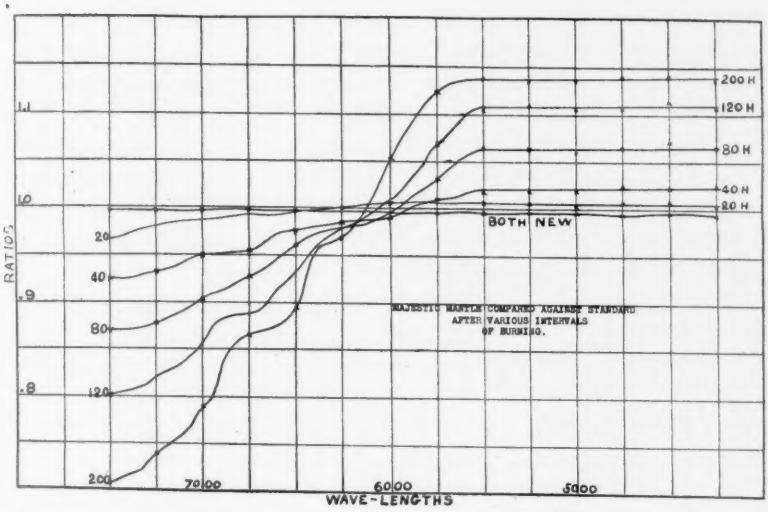
200 H
120 H
80 H
40 H
20 H
BOTH NEW
RATIOS
1.1
1.0
.9
.8
20
40
80
120
200
MAJESTIC MANTLE COMPARED AGAINST STANDARD
AFTER VARIOUS INTERVALS
OF BURNING.
7000
6000
5000
WAVE-LENGTHS

FIG. 7.

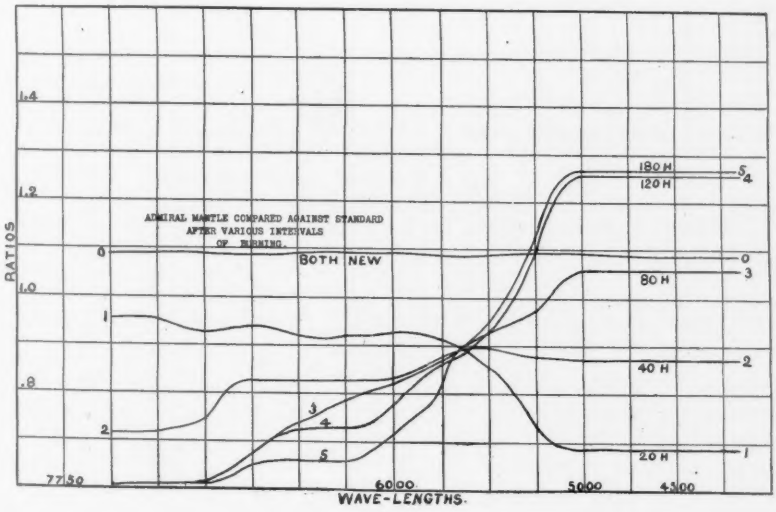
1.4
1.2
1.0
.8
RATIOS
ADMIRAL MANTLE COMPARED AGAINST STANDARD
AFTER VARIOUS INTERVALS
OF BURNING.
BOTH NEW
180 H
120 H
80 H
40 H
20 H
0
1
2
3
4
5
7750
6000
5000
4500
WAVE-LENGTHS.

FIG. 8.

It hardly seems worth while to burden this article with tables of figures obtained in the tests with the spectrophotometer, especially as the plots show the relation of the curves very clearly, and it is the nature of the changes rather than the particular values obtained which is of interest here.

Figure 6 gives the curves for the Yusea mantle, showing the changes at five selected intervals; these show clearly the progressive character of the changes and are sufficient for the purpose. The curves for the remainder of the intervals would simply serve to complicate the figure without adding anything material.

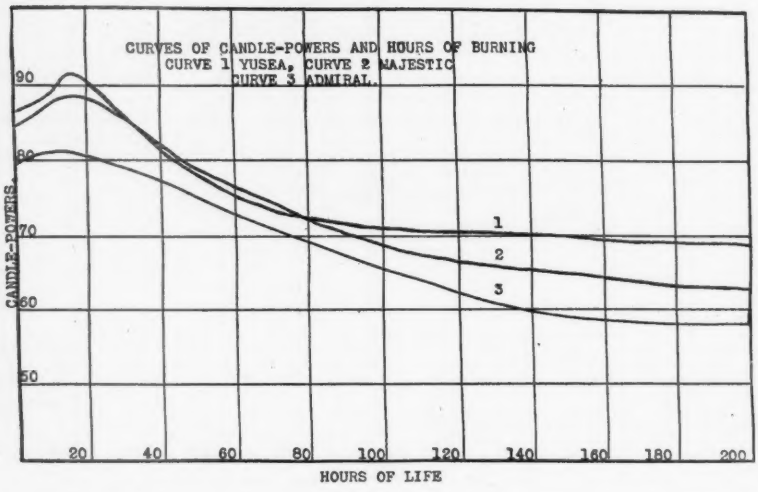

FIG. 9.

Figure 7 gives a similar set of curves for the Majestic mantle, and Figure 8 for the Admiral.

It will be noticed that there is in each case a point in the yellow or orange where the curves intersect, although this is much more marked in the Majestic and Admiral than in the Yusea. In this latter the curves weave in together at several points, and in this connection it is interesting to note that the Yusea is a mantle tending toward a yellowish green, while the other two both tend toward a bluish green.

The curves of Figure 9 are the candle-power variations with hours of burning for the three mantles. Each of these curves shows a

maximum after the mantle has burned a few hours, and from thence on a steady decrease, which, however, is hardly appreciable after the first hundred hours. This change, as well as those affecting the color of the light emitted, is probably due to the varying volatility of the chemical constituents of the mantle, so that in the earlier portion of its life the composition is changing rapidly, and later on more and more slowly.

As a result of this work I settled upon the Yusea as the best mantle for use in important places, with either the Majestic or Admiral in less important ones; I should choose the Majestic to replace the Yusea when it was not desired to use as high a priced mantle as the Yusea, and I should use the Admiral instead of the Majestic in places where I feared rough usage, as, although not quite so efficient, it appears to stand hard treatment rather better.

Of course the mantle, of whatever style it might be, ought not to be used without some pattern of diffusing shade, and this shade (or the chimney inside of the shade) ought to be tinted so as to correct so far as possible for the peculiar hue of the light, changing it over either to a fairly good white or to the more usual hue of artificial house illuminants.

Tests on Shades and Chimneys.

I had a selection of nine globes of the shape of an egg, open at both ends, as follows:

2nd. Prismatic glass (vertical inner ribs).
3rd. White Holophane glass.
4th. Pink Holophane glass.
5th. Robin's Egg Blue, fluted opal glass.
6th. Pale Green, fluted opal glass.
7th. Orange Yellow, fluted opal glass
8th. Rose Pink, fluted opal glass.
9th. Ruby, fluted frosted glass.
10th. White, fluted opal glass.

Also six chimneys (such as I could find in the Boston office of the Welsbach Company), as follows: —

2nd. Thin Greenish-blue glass.
3rd. Amber glass.
4th. Rather thick White opal glass.
5th. Dark Green glass.

6th. Dark Red glass.

7th. Dark Blue glass.

None of these chimneys would be of value except for producing color-effects in advertising, etc., but it is of interest to see what their use means in waste of light.

As a standard of white light for interior use I chose the Nernst lamp fitted with a thin globe of frosted glass for diffusion. In order that one may see about what this light is compared with various others, I give in Figure 10 some curves of comparison. In obtaining these curves the standard slit of the photometer was turned toward the clear overhead sky, near noon on a day in early spring, so that the light falling on the slit was about what would fall on a sheet of paper shaded from the direct rays of the sun and far away from any source of colored reflected light, such as foliage, brick walls, etc.

If this is assumed as the unit for each wave length, then the curves of Figure 10 show the relative proportion of light of each wave length present in the different flames: —

Curve 1. The Yusea mantle at 11.30 A.M.

Curve 2. The Acetylene flame at 11 A.M.

Curve 3. The Argand burner at 12 M.

Curve 4. The Nernst lamp at 12.25 P.M.

Curve 5. The Enclosed 110 V. D.C. arc lamp, with thin opal inner globe and clear outer, at 1 P.M.

Curve 6. The same Yusea mantle at 5 P.M.

This last is interesting as showing how the sky light has changed in character toward sunset.

These curves are purely relative, and the scale of ordinates merely furnishes a convenient scale for comparing the curves. It does not mean, for instance, that the acetylene flame has thirty-one times as much deep red in it as the sky, and about an equal amount of violet, but only that the ratio of red to violet is about 31 : 1, whereas, in this particular sky light, by hypothesis it was 1 : 1.

It will be seen that the Nernst, Acetylene, and Argand are nearly the same from $\lambda = 4250$ to $\lambda = 6000$, that the Acetylene contains rather more light of the hue of the α line of hydrogen than either Nernst or Argand, while the Argand contains more light of the deep red hue of the neighborhood of the α line of potassium than they do.

The peculiar color of the Welsbach is indicated by the preponderance of hues due to the shorter wave-lengths over the others, there being, for instance, about double the quantity of light of the hue of

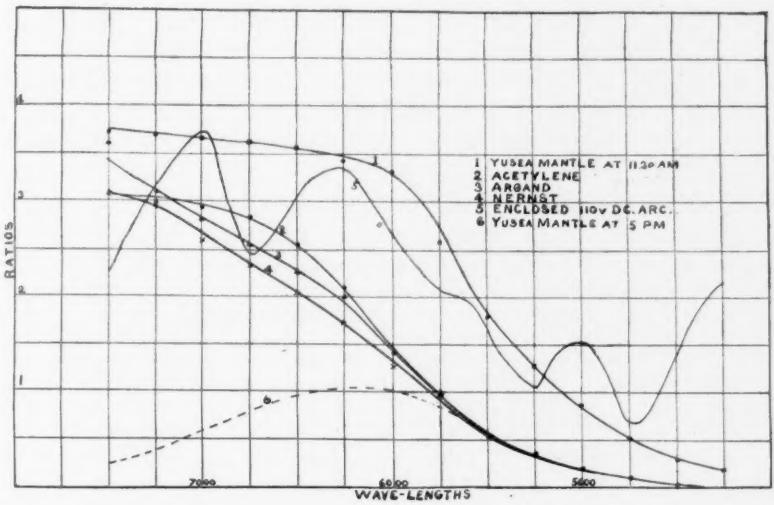
1 YUSEA MANTLE AT 1130 AM
2 ACETYLENE
3 ARGAND
4 NERNST
5 ENCLOSED 110v DC. ARC.
6 YUSEA MANTLE AT 5 PM
RATIOS
WAVE-LENGTHS
7000
6000
5000

FIG. 10.

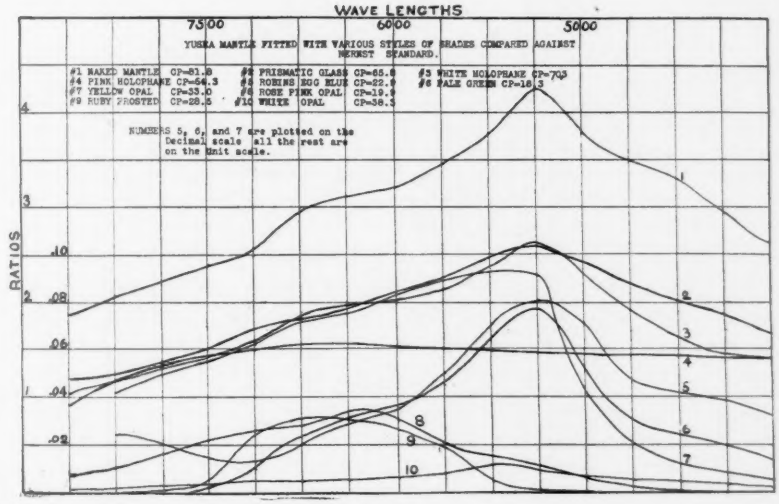
WAVE LENGTHS
7500
6000
5000
YUSEA MANTLE FITTED WITH VARIOUS STYLES OF SHADES COMPARED AGAINST NERNST STANDARD.
#1 NAKED MANTLE CP=81.8
#2 PRISMATIC GLASS CP=65.6
#3 WHITE MOLOPHANE CP=70.5
#4 PINK MOLOPHANE CP=54.3
#5 ROBINS EGG BLUE CP=22.9
#6 PALE GREEN CP=18.3
#7 YELLOW OPAL CP=33.0
#8 ROSE PINK OPAL CP=19.9
#9 RUBY FROSTED CP=28.5
#10 WHITE OPAL CP=38.3
NUMBERS 5, 6, and 7 are plotted on the Decimal scale all the rest are on the Unit scale.
RATIOS

FIG. 11.

the sodium flame, about three times as much of the hue of thallium green, and four times that of the hue of the β line of hydrogen.

In Figure 11 are given the curves of the different shades that were studied placed over a Yusea mantle; Curves 5, 6 and 7 being plotted on the decimal scale of ordinates, and all the others on the unit scale. These three curves, unless magnified, would lie underneath Curve 10 entirely.

None of the shades begin to compensate for the superabundance of green shown by the naked mantle, except Number 4, which is the mean of half a dozen pink Holophanes. This shade gives almost a

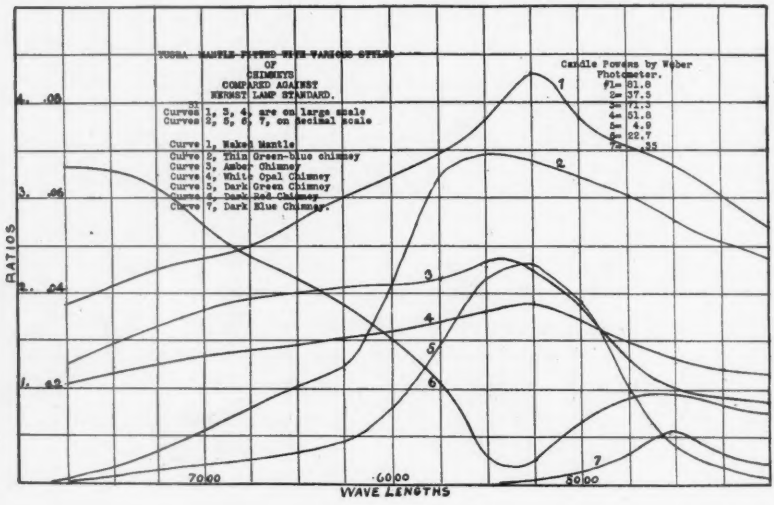

FIG. 12.

straight line between $\lambda = 6750$ and $\lambda = 4500$. Were it not for the slight rise at $\lambda = 6250$ and the drop in the violet, the color of the transmitted light would be hardly distinguishable from that of the Nernst. As it is, there is the faintest suspicion of pink in the light which can hardly be distinguished by the eye. Unfortunately it seems impossible at present to ensure absolute uniformity in this tint of pink, but the shades hardly vary sufficiently to count, in view of the variable color of the light emitted by the mantle, so that I feel quite confident in stating that so far as I am aware the nearest approach to a good quality of white light with the Welsbach system is to be attained by the use of this combination.

The following Table gives the candle-powers found by the Weber Photometer, and hence a measure of the light lost; but it should be understood that since the candle-power given is horizontal and not mean spherical, the two Holophanes cannot be directly compared with the others, since these two differ widely from the others in their action on the light.

TABLE 5.

NUMBER OF CURVE.	SHADE.	CANDLE-POWER.	PER CENT. LOSS.
1	Naked Mantle.	81.80	
2	Prismatic Glass.	65.80	19.6
3	White Holophane.	70 30	14.1
4	Pink Holophane.	64.30	20.8
5	Robin's-Egg Blue Opal.	22.90	72.2
6	Pale Green Opal.	18 30	77.8
7	Yellow Opal.	33.00	59.7
8	Rose Pink Opal.	19.90	75.6
9	Ruby Frosted.	28.50	65.2
10	White Opal.	38 30	53 2

Figure 12 is a plot for the chimneys examined. Curves 1, 3 and 4 are on the unit scale, the others on the decimal scale. Table 6 gives the candle-power transmitted.

TABLE 6.

NUMBER OF CURVE.	CHIMNEY.	CANDLE-POWER.	PER CENT. LOSS.
1	Naked Mantle.	81 80	
2	Thin Green Blue.	37 50	54.2
3	Amber.	71.30	12 8
4	White Opal.	51.80	36.7
5	Dark Green.	4.90	92 8
6	Dark Red.	22.70	72.3
7	Dark Blue.	0.35	99.6

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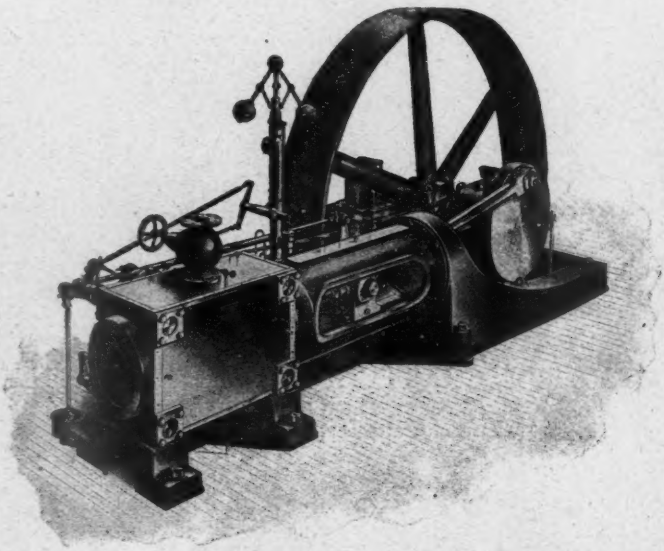

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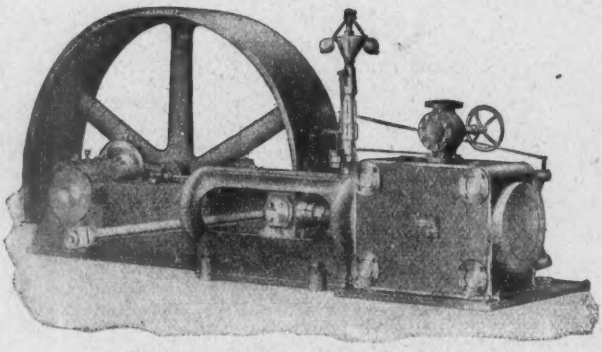

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